

## CONVERSION TABLE

Multiply inch-pound units	By	To obtain metric SI units
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
gallon per minute (gal/min)	0.0631	liter per second (L/s)

Micrograms per liter ( $\mu\text{g/L}$ ) and milligrams per liter ( $\text{mg/L}$ ) are standard reporting units.

## ABSTRACT

Arsenic, nitrate, iron, and hardness in well water are concerns of homeowners and planners in the Fairbanks North Star Borough, Alaska. Arsenic and nitrate in water may affect human health. Iron and hardness can be aesthetically objectionable, impair plumbing systems, and discolor plumbing fixtures.

This report is a compilation of the arsenic, nitrate, iron, and hardness data collected through February 1983 in the Goldstream Road, Murphy Dome Road, and Yankovich-Miller Hill Road areas of Fairbanks. Within these areas, concentrations of arsenic ranged from 0 to 1600 micrograms per liter, nitrate (as nitrogen) ranged from 0 to 78 milligrams per liter, iron ranged from 0 to 46 milligrams per liter, and hardness (as calcium carbonate) ranged from 34 to 1220 milligrams per liter.

## INTRODUCTION

The U.S. Geological Survey (USGS), in cooperation with the Fairbanks North Star Borough, has conducted studies of the water resources of the Fairbanks area since 1975. One of the objectives of these studies is to collect and compile the basic data needed to appraise the occurrence, quantity and quality of the resources, as well as to provide a reference from which any significant changes in the hydrologic environment can be measured.

This is the fourth water-quality data report published in cooperation with the borough. The first, by Johnson and others (1978), is a compilation of all the arsenic, nitrate, iron, and hardness data collected by various agencies through September 1978. The USGS collected additional data in the Chena Ridge area through 1979 (Krumhardt, 1980) and in the Gilmore Trail, Steele Creek Road, and Chena Hot Springs Road areas through 1981 (Krumhardt, 1982).

This report contains arsenic, nitrate, iron, and hardness data collected as of February 1983 in the Goldstream Road, Murphy Dome Road, Yankovich Road, and Miller Hill Road areas. Data from the report by Johnson and others (1978) and from the files of the Alaska Department of Environmental Conservation (DEC) are also included. Because samples were collected as part of different study programs, data on all four variables were not obtained at all wells. For example, DEC sampled only for arsenic and nitrate, the Center for Disease Control (CDC) sampled only for arsenic, and the U.S. Environmental Protection Agency (EPA) only for nitrate. The USGS generally did not sample for arsenic prior to 1975.

Sampling sites were selected either by contacting homeowners for permission or at their request; therefore not all wells in the area were sampled. Data are sparse or lacking in areas of little or no development and, conversely, are concentrated where development is most intense. This report should be used only as an indicator of those areas in which undesirable or "nuisance" levels of the four chemical variables occur. Other areas and individual wells not included in this report should be sampled to confirm the presence or absence of any water-quality problems.

At each well visited by USGS personnel, field tests or measurements included water temperature, pH, alkalinity, and specific conductance in addition to those for arsenic, nitrate, iron, and hardness. Samples for laboratory analysis of arsenic and hardness were routinely collected from each well visited; samples for analysis of nitrate and iron were collected only if field tests for these constituents were positive. Water levels in the sampled wells were measured where possible. All data in this report, and additional details on some of the wells sampled, are on file at the Fairbanks office of the USGS, Water Resources Division, Room 168, Federal Building and U.S. Courthouse.

## Physiography and Geology

This study area is on the southern perimeter of the Yukon-Tanana uplands. More specifically, the area of data collection is encompassed by Ester Dome on the southwest, the Tanana River valley to the south, and the Chatanika River valley to the north. The headwaters of Sheep Creek, Eva Creek, Frenchman Creek, and St. Patrick Creek are all included in the area of study. The Goldstream Creek valley bisects the study area.

The uplands are composed primarily of a pelitic schist (metamorphosed marine mud deposit) and micaceous quartzite bedrock (Péwé and others, 1976). The bedrock has been buried to various depths by eolian (wind blown) silt, or loess, drifted from the Tanana River valley and onto the hills to the north (Krumhardt, 1982). The loess is thickest on the slopes nearest the Tanana River flood plain and thins northward from the valley. On the slopes adjacent to the Tanana River valley, the silt cover is thickest at the bottom of the slope and thins or is absent on hill-tops. On the lower slopes and valley floors, the loess has been reworked and is locally referred to as muck. This muck may be perennially frozen and in places has a high ice content. It commonly overlies coarse gravel in the creek valley bottoms but rests on bedrock on the upper slopes.

## Area Hydrology

The uplands, arbitrarily defined as those hills having an altitude greater than 500 ft, are underlain by an aquifer system unlike that of the lowlands. Water in the upland aquifers may not be replenished as fast as it is used due partly to a combination of low annual precipitation (10-12 in.), rapid runoff from the silty topsoil, and low rates of recharge and transmission of ground water through the fractured and faulted bedrock. Yields of residential wells average about 5 gal/min, but yields as high as 15 gal/min and as low as 1 gal/min have been reported. The higher yields ordinarily can be obtained only from wells drilled in the depressions marking the courses of former stream valleys (Cederstrom, 1963). On the lower slopes and in valleys, permafrost may prevent both recharge to and discharge from the underlying aquifer. The permafrost acts as a confining barrier, causing wells, springs, or seeps to have an artesian hydraulic head, which some homeowners have controlled and effectively used in their plumbing systems. However, many drillers will not drill in these areas due to the possibility of uncontrolled flows in the open area around the well casing. Controlling such flow may be extremely difficult and costly.

## CHEMICAL CHARACTERISTICS

## Arsenic

Arsenic in water is a tasteless, colorless, and odorless constituent that is not removed by water treatment systems commonly used by homeowners. A dosage of 70,000  $\mu\text{g}$ , or less than 1 ounce of pure arsenic, is toxic to most humans (Luh and others, 1977). The toxic level varies with individuals and probably depends on the chemical form of the arsenic (National Academy of Sciences, National Academy of Engineering, 1972). Smaller amounts of arsenic ingested over a long period of time can accumulate in the body and produce chronic or acute symptoms. Indications of arsenic poisoning include fatigue, skin growths, nervous system disturbances, and gastrointestinal, kidney, and liver illnesses.

Concentrations of arsenic in the ground water sampled in the study area ranged from 0 to 1600  $\mu\text{g/L}$ . The U.S. Environmental Protection Agency (1977), and Alaska Department of Environmental Conservation (1979), have set a maximum limit of 50  $\mu\text{g/L}$  in water for human consumption. The arsenic concentration in 16 wells, about 14 percent of those sampled, exceeds that limit.

Local sources of arsenic and the process by which it enters the ground water have not been thoroughly investigated. However, zones of mineralized bedrock in the Fairbanks uplands contain arsenic-bearing minerals such as arsenopyrite ( $\text{FeAsS}$ ) and scorodite ( $\text{FeAsO}_4 \cdot 2\text{H}_2\text{O}$ ). Arsenic from these zones can be slowly leached into the ground water by chemical and physical weathering. Research in the Ester Dome area has shown that the bedrock contains 750 parts per million arsenic (Hawkins and others, 1982).

## Nitrate

The element nitrogen (N) occurs in ground water in many forms, including nitrate ( $\text{NO}_3$ ), nitrite ( $\text{NO}_2$ ), and ammonium ( $\text{NH}_4$ ). Nitrate, the most common form, is colorless and odorless and is not removed by water-treatment systems used by most homeowners. Excessive amounts of nitrate may cause a bitter taste (Miller, 1980). Human consumption of water with more than 10  $\text{mg/L}$  of nitrate (as nitrogen) has been related to hypertension, cancer, and in some infants under 3 months of age, potentially fatal anemia. Bacterial breakdown of the nitrate ion to the nitrite ion may occur in the digestive tract of babies 3 months of age or less (National Academy of Sciences, National Academy of Engineering, 1972). Nitrite absorbed into the bloodstream combines with the hemoglobin, reducing the oxygen-carrying capacity of the blood. The resulting methemoglobinemia is oxygen starvation, which causes the so-called "blue baby," a condition which can be recognized and treated. However, many infants have consumed water containing more than 10  $\text{mg/L}$  nitrate with no ill effects. Factors which may affect susceptibility to nitrate poisoning include heredity, the ingestion of nitrate-rich vegetables and vitamin-C-rich foods, and the use of certain medications which affect nitrate metabolism.

Because of the possibility of causing methemoglobinemia, hypertension, and cancer the EPA has established the recommended maximum concentration of nitrate-nitrogen in drinking water at 10  $\text{mg/L}$ . Water sampled from wells in the study area had nitrate-nitrogen concentrations between 0 and 78  $\text{mg/L}$ . The EPA limit was exceeded in 11 wells, about 12 percent of those sampled.

## Iron

Small amounts of iron create an undesirable taste or odor in water, and can cause staining of laundry, appliances, and hair. Staining caused by water with concentrations of iron less than 1  $\text{mg/L}$  can be controlled effectively by cleaning agents and bleaches. At concentrations between 1 and 3  $\text{mg/L}$ , water may become unpalatable, and staining becomes more difficult to control. Water containing more than 3  $\text{mg/L}$  of iron is unacceptable to most people because it can turn alcohol the color of black coffee. At this concentration staining generally can be controlled only by using iron filters. When iron-rich water is oxygenated, as it is in home water systems, the iron precipitates to cause reddish-brown stains. Household water-treatment systems which oxidize the water and then filter the iron residue are commercially available. Based on the above considerations, three ranges of iron concentrations are portrayed on the study map: less than 1  $\text{mg/L}$ , 1 to 3  $\text{mg/L}$ , and greater than 3  $\text{mg/L}$ .

Iron concentrations in well waters commonly increase in a downslope direction. This increase may be caused by inorganic oxidation reactions occurring as the water moves from higher areas toward the valleys. It may also result from exposure of percolating ground water to buried organic debris. The decomposition of organic matter in soils consumes oxygen from ground water, producing an oxygen-deficient environment in which iron is more readily dissolved. Such conditions are common in the alluvium of the Tanana River flood plain and in creek valley bottoms. Iron concentrations in these areas are almost always greater than 1  $\text{mg/L}$  and commonly greater than 3  $\text{mg/L}$ .

Certain bacteria enhance the precipitation and oxidation of iron (Hem, 1970). These bacteria, which are present in many wells, cause some of the iron to precipitate before it reaches the pump inlet. They produce a jelly-like slime that may plug the pore space in the aquifer near the wells and hinder the inflow of water. Fragments of these bacterial growths can break loose and plug filters and pipes. Heavy chlorination of wells at frequent intervals minimizes the growth of iron bacteria; however, once the bacteria are established in an aquifer near a well, there is no known method of effectively removing or destroying them.

The EPA's recommended limit for iron of 0.3  $\text{mg/L}$  is based on aesthetic considerations rather than health reasons. In the study area, iron concentrations ranged from 0 to 46  $\text{mg/L}$ . Sixty-one percent of the samples (42 wells) contained less than 1  $\text{mg/L}$  iron. Thirteen percent (9 wells) contained from 1 to 3  $\text{mg/L}$  iron, and 27 percent (18 wells) contained iron in concentrations greater than 3  $\text{mg/L}$ . The recommended limit was exceeded in 57 percent of the samples (39 wells).

## Hardness

Hardness of water is caused primarily by the occurrence of dissolved magnesium and calcium. It is expressed as an equivalent concentration of calcium carbonate ( $\text{CaCO}_3$ ). Hard water not only retards the cleaning action of detergents and soaps but may also form crusts on cookware, in water heaters, and in boilers. Hardness can be controlled by commercially available softeners. Hard water has been known to have positive effects and some people prefer it. In the United States, a tentative correlation has been found between areas of hard water and areas where the death rate from cardiovascular diseases is lower than average (Muss, 1962).

Hem (1970) reported that waters having less than 100  $\text{mg/L}$  hardness (as  $\text{CaCO}_3$ ) are usually acceptable for domestic use although the optimum amount is a matter of consumer preference. At levels greater than 200  $\text{mg/L}$ , hardness is noticeable in all uses. The EPA has set no minimum or maximum standards for hardness of water. Using Hem's observations, three ranges of hardness are shown on the study map: less than 100  $\text{mg/L}$ , 100 to 200  $\text{mg/L}$ , and greater than 200  $\text{mg/L}$ .

Ground-water samples from the study area ranged in hardness from 34 to 1220  $\text{mg/L}$   $\text{CaCO}_3$ . Of the wells sampled, 16 percent (11 wells) had less than 100  $\text{mg/L}$  hardness, 21 percent (15 wells) were in the 100 to 200  $\text{mg/L}$  range, and 63 percent (44 wells) had greater than 200  $\text{mg/L}$  hardness. It is interesting to note that all wells in which hardness is less than 100  $\text{mg/L}$  are above 750 ft in altitude. In spite of this coincidence, several wells with hardness values greater than 100  $\text{mg/L}$  are shown above the 750-foot level.

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## CHEMICAL ANALYSES

[a, field determination using HACH\* test kit NI-12; b, field determination using HACH\* test kit IR-18B; c, arsenic and nitrate sample collected between February 1976 and September 1977.]

\* The use of the brand name in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Map No.	Location	Arsenic (As) (µg/L)	Nitrate (NO <sub>3</sub> as N) (µg/L)	Iron (Fe) (mg/L)	Hardness (as CaCO <sub>3</sub> ) (mg/L)	Sampling date	Sampling agency
Sec. 1							
1		1	1.7	0.3	130	03-05-82	USGS
2		<1	1.1	.2	60	12-07-81	USGS
3		<1	.8	.1	100	02-16-82	USGS
4		<1	1.1	.3	66	12-08-81	USGS
5		<1	.1	9.8	150	12-08-81	USGS
6		<1	1.5	.1	100	12-08-81	USGS
Sec. 7							
2		1	.3	.5	99	11-04-81	USGS
3		1	.1	—	120	11-16-81	USGS
6		0	<1a	15	<100	10-13-76	USGS
7		1	.2	6.4	100	11-04-81	USGS
11		0	.4	.9	75	06-28-79	USGS
12		0	.5	.3	160	05-27-80	USGS
13		1	.6	.1	34	11-03-81	USGS
14		1	.1	1.9	110	11-04-81	USGS
15		2	.1	4.7	230	11-13-81	USGS
16		1	.5	1.1	80	11-13-81	USGS
17		1	.2	.4	140	11-16-81	USGS
18		<1	<1	.4	150	12-03-81	USGS
19		<1	.3	.8	84	12-03-81	USGS
Sec. 8							
2		<1	.3	.1	320	06-29-82	USGS
Sec. 9							
3		<1	15	<.1	380	03-04-82	USGS
4		1	.7	11	350	02-26-82	USGS
5		1	5.9	1.9	380	04-20-82	USGS
6		<1	.7	.1	360	06-28-82	USGS
7		<1	1.1	.1	320	06-30-82	USGS
Sec. 10							
1		<1	.1	6.4	240	02-11-82	USGS
2		<1	.2	.8	110	02-11-83	USGS
3		<1	--	--	--	c	DEC
Sec. 11							
4		9	.1	<.1	230	02-16-82	USGS
5		--	.3	--	--	03-05-74	EPA
6		16	0	--	--	c	DEC
7		2	14.7	--	--	c	DEC
Sec. 12							
3		1	74	.2	1100	02-23-82	USGS
4		0	<1a	1b	274	04-09-77	USGS
8		1	.6	.3	300	01-06-82	USGS
9		<1	3.7	.5	510	11-19-81	USGS
12		1	3.8	.3	800	11-19-81	USGS
13		1	1.2	.2	260	11-19-81	USGS
14		<1	1.8	<.1	390	01-12-82	USGS
15		<1	.5	.2	94	01-12-82	USGS
16		<1	.7	3.2	320	01-16-82	USGS
18		1	5.3	<.1	380	02-11-82	USGS
19		1	24	.3	550	02-23-82	USGS
20		1	.1	1.7	260	02-25-82	USGS
21		1	26	7.3	1200	02-23-82	USGS
22		1	.1	3.1	880	02-18-82	USGS
23		0	0	--	--	c	DEC
24		0	6.8	--	--	c	DEC
25		2	1.7	--	--	c	DEC
26		--	.5	--	--	12-72	EPA
27		35	4.8	--	--	c	DEC
28		<1	--	--	--	c	DEC
29		1	--	--	--	c	DEC
30		--	.1	--	--	07-71	EPA
31		<1	.4	--	--	c	USGS
32		<1	--	--	--	03-24-82	DEC
33		<1	1.1	--	--	10-02-79	DEC
Sec. 13							
4		10	.1	12	440	12-07-81	USGS
Sec. 14							
1		--	.1	.3	192	09-29-66	USGS
2		8	--	--	--	08-29-75	USGS
3		0	1.8	--	--	c	DEC
4		16	10.5	--	--	c	DEC
5		0	--	--	--	c	DEC
6		37	--	--	--	c	DEC
7		0	7.3	--	--	c	DEC
8		23	--	--	--	c	DEC
Sec. 15							
1		<1	2.7	1.8	472	08-25-75	USGS
6		<1	5.1	--	--	04-01-80	DEC
9		0	2a	0b	240	08-24-79	USGS
11		1	30	12	650	02-11-82	USGS
12		<1	--	--	--	c	DEC
13		<1	2.1	--	--	c	DEC
14		<10	--	--	--	c	DEC
15		<1	--	--	--	c	EPA
16		<1	--	--	--	c	DEC
17		2	--	--	--	c	DEC
Sec. 21							
2		29	--	--	--	08-26-75	USGS
3		3	--	--	--	08-27-75	USGS
4		52	.2	46	260	08-17-82	USGS
Sec. 25							
1		270	1.5	.2	219	09-30-76	DEC
3		--	<.1	9.8	1220	08-18-54	USGS
4		540	1.4	.1	120	04-08-79	USGS
5		2	2	.3	210	04-10-79	USGS
6		27	3.6	.1	320	04-21-79	USGS
7		22	1.8	.5	190	04-20-79	USGS
8		190	0a	.6b	360	04-08-79	USGS
10		4	--	--	--	c	DEC
11		--	3	--	--	06-72	DEC
12		5	78	--	--	09-14-82	DEC
13		50	<.1	--	--	09-14-81	DEC
14		720	<.1	--	--	08-06-81	DEC
15		<5	2.7	--	--	08-01-80	DEC
16		82	1.1	--	--	07-25-80	DEC
17		360	--	--	--	06-17-80	DEC
18		40	--	--	--	09-07-79	DEC
19		<50	--	--	--	c	EPA
Sec. 26							
1		23	--	--	--	08-20-75	USGS
3		1600	.1	2.4	220	04-01-82	USGS
Sec. 27							
3		1100	<.1	13	460	02-18-76	USGS
4		2	3.3	2.9	590	06-22-82	USGS
5		2	3.6	4.1	530	04-29-82	USGS
Sec. 28							
5		21	21	2.2	490	07-16-82	USGS
6		140	16	.1	290	08-13-82	USGS
Sec. 31							
1		10	.1	5.6	80	02-11-82	USGS
3		9	.3	18	54	02-25-82	USGS
Sec. 35							
1		52	--	--	--	08-25-75	USGS
3		37	--	.2	890	01-28-82	USGS
4		90	.9	.3	170	01-28-82	USGS
5		546	13	.5	610	01-28-82	USGS
6		--	--	--	--	08-25-75	USGS
7		0	.7	.7	258	07-01-69	USGS
8		94	3.8	.2	830	01-25-82	USGS
9		3	--	--	--	c	DEC
10		80	.6	.7	258	c	USGS
11		850	--	--	--	04-08-80	DEC
Sec. 36							
2		5	--	--	--	c	USGS
3		1	3.8	13	1000	01-25-82	USGS